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Analysis and Control of Nonsmooth Dynamical Systems

Camlibel, M. Kanat; Nijmeijer, Henk

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Editorial

Analysis and Control of Nonsmooth Dynamical Systems

Mainstream systems and control theory have been built in the realm of the *smooth* world. As such, modeling, analysis, and synthesis of smooth control systems take lion's share of the entire literature of systems and control theory. However, one often encounters nonsmooth phenomenon in various branches of science and engineering. Besides this variety of context, the way that nonsmoothness arises varies in a wide range. Sometimes, for instance, nonsmoothness is due to the intrinsic abrupt changes in the dynamics. Sometimes, though, it emerges as a consequence of ideal modeling of fast dynamics as sudden changes or approximating nonlinearities with piecewise linear characteristics. Also, the interaction of continuous and discrete dynamics results in nonsmooth systems. To exemplify this variety, one can consider the following typical application areas: mechanics (contact and friction problems), electrical engineering (circuits with switching and/or piecewise linear elements), hydraulics (one-way valves), mathematical programming (dynamic optimization subject to inequality constraints), and mathematical finance (pricing of derivatives with early exercise opportunities).

Although the theory of smooth systems plays still an important role in the framework of nonsmooth systems, the vast majority of problems in nonsmooth dynamical systems call for completely new methodologies. In the past, a large collection of various problems of nonsmooth systems has been investigated within several fields. These efforts already resulted in a substantial literature in the corresponding fields. Recent years have witnessed, on one hand, an increasingly growing interest in nonsmooth systems and, on the other hand, a trend in collaboration among various fields; ranging from dynamical systems to mathematical programming, from mechanics to numerical analysis, from operations research to computer science. Indeed, many researchers from these and related areas combined their efforts in resolving the challenges of nonsmooth systems. Examples of such gatherings are, for instance, European Commission supported project of SICONOS (modeling, SIMulation and CONtrol of NONsmooth dynamical Systems) and, on the other side of the Atlantic, NSF supported project of DA VINCI (Differential Algebraic and Variational INequalities in Control and sImulation). All these multi-disciplinary efforts produced a good deal of literature on the analysis and synthesis of nonsmooth dynamical systems. An inevitable consequence of the nature of such systems is that the available literature is rather eclectic. The aim of this special issue is to sketch a picture of the mosaic of the multi-disciplinary and eclectic theory of nonsmooth dynamical systems.

The three papers presented in this special issue emphasize three different lines of research in the field of nonsmooth dynamical systems:

Semicopositive Linear Complementarity Systems (by J. Shen and J.-S. Pang)

This paper studies well-posedness of a class of nonsmooth systems that is known as linear complementarity systems. Well-posedness in the context of nonsmoothness is a relevant issue for several reasons including model validation. The paper presents conditions under

which solutions to a linear complementarity system exist and are unique. As it combines ideas and methods of mathematical programming and systems theory, the paper reflects the multi-disciplinary nature of the theory of nonsmooth dynamical systems.

Observer design for a class of piecewise linear systems (by A. Lj. Juloski, W. P. M. H. Heemels, and S. Weiland)

The issue of observer design, which is a powerful tool in design of controllers, is addressed in this paper. As the results of the paper indicate, observer design for even piecewise linear systems is not a mere extension of the available results of theory of smooth systems. By taking a linear matrix inequality approach, the authors provide sufficient conditions under which one can design Luenberger-type observers for bi-modal piecewise linear systems that may have either continuous or discontinuous dynamics.

On the stabilizability of near-grazing dynamics in impact oscillators (by H. Dankowicz and F. Svahn)

The focus of this paper is near-grazing dynamics in vibro-impacting oscillators. It gives a constructive proof for the existence of event-driven control strategies that guarantee the local persistence of system attractors. The implications of the methodology are illustrated by a number of examples of linear and nonlinear vibro-impact oscillators. The paper gives a good example of fusion of ideas from bifurcation theory and control theory.

In conclusion, we believe this special issue provides a valuable addition in the existing and challenging field of nonsmooth control systems. We would like to thank the authors and all reviewers for their very much appreciated contributions to this special issue.

M. KANAT CAMLIBEL

*Eindhoven University of Technology, The Netherlands
Dogus University, Turkey*

HENK NIJMEIJER

Eindhoven University of Technology, The Netherlands